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## Military Ground Vehicle Silicon Carbide Needs

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TARDEC

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- *Fielded Combat Vehicle Electrical Systems are maxed out*
- *New/Modernizing Combat Vehicles have 28VDC requirements  $\geq 30\text{kW}$  across all operating profiles*
  - *Stryker SMOD SPS: “capable of supplying 30 kW continuous 28 VDC electrical power, not to be provided by an energy storage device, across the entire operating range of the engine”*
  - *GCV CDD: “capable of generating 45 kilowatts (kW) of quality sustained electric power...”*
- *Alternator technology has reached its max feasibility (25.5-28kW) and new approaches/technologies are required to achieve higher electrical power output*
- *Desires exist to electrify large motor loads: Air-conditioning, propulsion cooling fans, turret drive motors, etc. to gain more horsepower and fuel efficiencies*

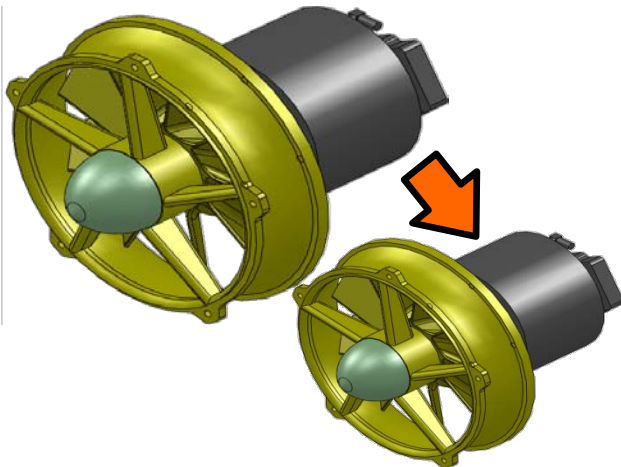
**New approaches for electrical power systems are required on  
Military Ground Vehicles**

- ***Stryker Modernization chose a 600VDC architecture to meet its requirements in 2010. PM-SBCT & GDLS are revisiting that decision this summer due to schedule and integration risks***
- ***All JLTV technology development vendors chose a different high voltage solution to meet their electrical power requirements***
- ***It is likely 600VDC architecture will be chosen for all platforms where the 28VDC requirement exceeds 28kW across all engine operating speeds***

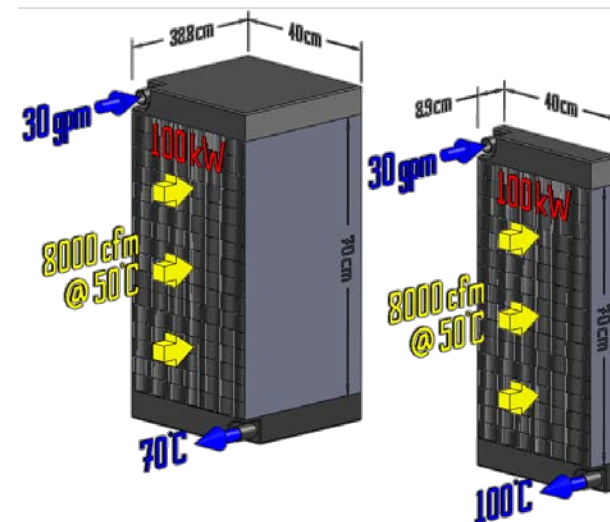
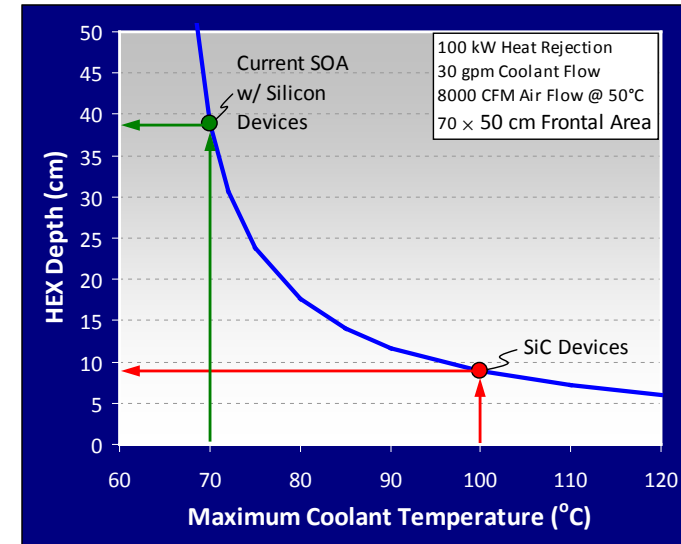
- ❑ ***Cannot package HV power system electronics with accompanying air-conditioning and engine upgrades without making some trades***
  - ***SWAP of Si-based electrical system not acceptable***
    - ***Size and weight of the converters***
    - ***Low operating temperature – large cooling system***
    - ***Significant power draw from the engine for the cooling fans***

# Improved Power Electronics Cooling Attributes

- Si based power electronics require coolant inlet Temperature not to exceed 70 or 80°C resulting in large cooling system size
- SiC can operate at much higher temperatures  $\geq 100^{\circ}\text{C}$  thus reducing the size of The cooling system by half



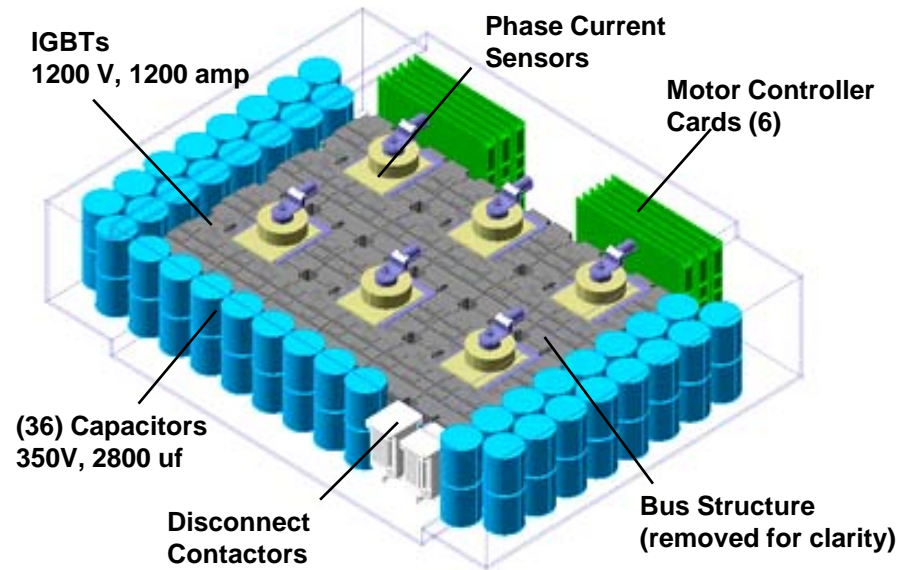
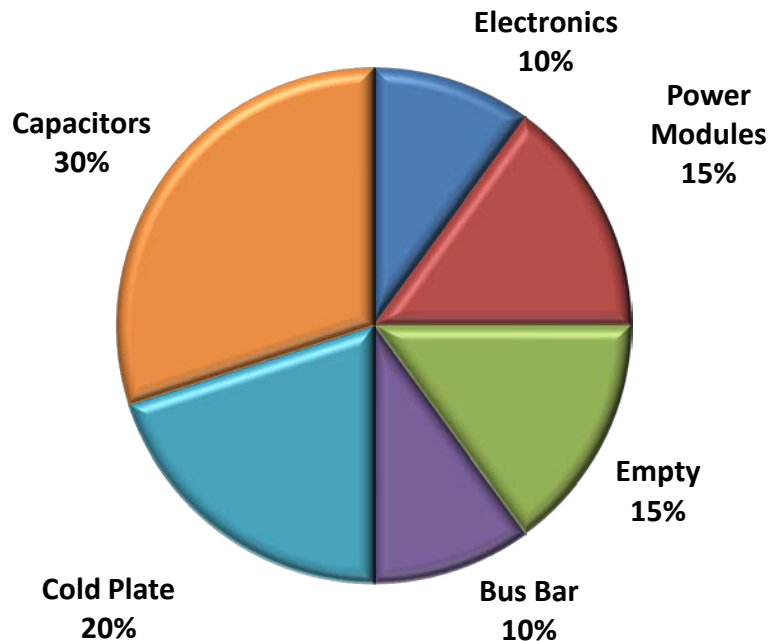
Advanced SiC Components will Reduce the Power Electronics Cooling Burden



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# Fewer Passive Components

Relative Volume of Power Converter Components



**SiC allows for higher frequency switching  
 leading to fewer capacitors and magnetics**



# ***MOTIVATION: Increased Performance, Reduced Integration Burden, & Fuel Savings***

## **Why SiC / high power electronic devices?**

Reduced SWAP, reduced cooling requirements, increased efficiency at high voltage, and higher operating temperatures. Overall, easier to integrate onto military ground vehicles than silicon based systems.

- **Size / Weight:** Up to 2X smaller and lighter compared to Si circuits.
- **Engine Power:** 70% more efficient than Si Circuits
  - **~5.3 HP gained for every kilowatt recovered of electronic loss**
- **Cooling:** Greater operating temperature (>100°C coolant) and efficiency means cooling system SWAP is significantly reduced
- **Reliability:** Si power electronics (80°C coolant) have no thermal margin. SiC switches (100°C) have up to 60°C margin and can provide some **'Limp Home' functionality**.

## **Continuing efforts:**

- Test and evaluation of SiC converters from ARRA efforts
  - 200 kW Traction Motor Drive Inverter
  - 50 kW Motor Drive Inverter for pumps, fans
  - 30 kW Bi-directional DC-DC converter (300Vdc to 28Vdc)
  - 180 kW Bi-directional DC-DC converter (300V Battery-to-600V Bus)
  - 30 kW AC Export Power Inverter 300Vdc-to -60Hz @ 10Vac, 220Vac & 208Vac (3-phase)

## **New Efforts:**

- ~160kW SiC Generator Inverter – BAA
- 10kW 600-28VDC SiC DC/DC Converter – TARDEC Omnibus

**TARDEC will be competitively looking for industry help to design these components in FY12**

## COST

- Power electronics for military applications are produced in low quantities, <1000/year in a production run
- The SiC module, the high temperature capacitors, and inductors are the major contributors to the high cost of SiC
- Complete SiC power electronics cost 5 times more, while offering better SWAP-C performance
- Improved manufacturing to increase the yield and larger quantity production are needed to reduce the cost of SiC to the same cost of Si
  - *We likely need commercial industry to adopt this technology in order for the production quantities to be sufficient enough to lower the cost for military use*

# Questions?